[NAME OF DOCUMENT] SPECIFICATION

[TITLE OF THE INVENTION] DEPOSITED-FILM FORMING APPARATUS

[SCOPE OF CLAIMS OF PATENT]

[CLAIM 1] A deposited-film forming apparatus comprising an evaporating section for a depositing material, and a tubular barrel formed of a mesh net for accommodation of work pieces, on each of the surfaces of which a depositing material is to be deposited, said evaporating section and said tubular barrel being mounted in a vacuum-treating chamber, wherein said tubular barrel is supported outside a horizontal rotary shaft of a support member rotatable about said rotary shaft, for rotation about said rotary shaft, so that the distance between said tubular barrel rotated about said rotary shaft of said support member and said evaporating section can be varied by rotating said support member.

[CLAIM 2] A deposited-film forming apparatus according to claim 1, wherein a plurality of said tubular barrels are supported in an annular shape outside said rotary shaft of said support member.

[CLAIM 3] A deposited-film forming apparatus comprising an evaporating section for a depositing material, and a tubular barrel rotatable about a horizontal rotary shaft and formed of a mesh net for accommodation of work pieces, on each of the surfaces of which a depositing material is to be deposited, said evaporating section and said tubular barrel being mounted in a vacuum-treating chamber, wherein the inside of said tubular

barrel is divided into two or more accommodating sections, said accommodating sections being defined, so that the distance between said accommodating section and said evaporating section can be varied by rotating said tubular barrel.

[CLAIM 4] A deposited-film forming apparatus according to claim 3, wherein the inside of said tubular barrel is divided radiately from a rotational axis into two or more accommodating sections.

[CLAIM 5] A process for forming a deposited film using a deposited-film forming apparatus according to any of claims 1 to 4.

[CLAIM 6] A process for forming a deposited film according to claim 5, wherein the work piece is a rare earth metal-based permanent magnet.

[CLAIM 7] A process for forming a deposited film according to claim 5 or 6, wherein the depositing material is at least one material selected from the group consisting of aluminum, zinc, tin and magnesium and an alloy containing at least one of these metal components.

[DETAILED DESCRIPTION OF THE INVENTION]

[0001]

[TECHNICAL FIELD TO WHICH THE INVENTION BELONGS]

The present invention relates to a deposited-film forming apparatus suitable for forming a deposited film of aluminum or the like on the surface of a work piece such as a rare earth metal-based permanent magnet.

[0002]

[PRIOR ART]

A rare earth metal-based permanent magnet such as an R-Fe-B based permanent magnet, of which an Nd-Fe-B based permanent magnet is representative, is used at present in a variety of fields, because it has a high magnetic characteristic.

However, the rare earth metal-based permanent magnet contains metal species (particularly, R) liable to be corroded by oxidation in the atmosphere. Therefore, when the rare earth metal-based permanent magnet is used without being subjected to a surface treatment, the corrosion of the magnet is advanced from its surface due to the influence of a small amount of acid, alkali and/or water to produce rust, thereby bringing about the deterioration and dispersion of the magnetic characteristic. Further, when the magnet having the rust produced therein is incorporated into a device such as a magnetic circuit, there is a possibility that the rust is scattered to pollute surrounding parts or components.

With the foregoing in view, it is a conventional practice to form a deposited film of aluminum or the like on the surface of a rare earth metal-based permanent magnet for the purpose of providing an excellent corrosion resistance to the rare earth metal-based permanent magnet.

An example of conventionally known apparatus used for forming a deposited film of aluminum or the like on the surface of a rare earth metal-based permanent magnet is shown in Fig.

5. Fig.5 is a diagrammatic front view of the inside of a vacuum-treating chamber 101 connected to an evacuating system (not shown) of such apparatus. Two cylindrical barrels 105, for example, formed of a mesh net of a stainless steel are disposed side-by-side in an upper area in the chamber for rotation about a horizontal rotary shaft 106. A plurality of boats 102, which are evaporating sections for evaporating aluminum as a depositing material, are disposed on a boat support base 104 risen on a support table 103 in a lower area in the chamber.

With this apparatus, a plurality of rare earth metal-based permanent magnets 130 as work pieces are placed into each of the cylindrical barrels 105, and aluminum is evaporated from the boats 102 heated to a predetermined temperature by a heating means (not shown), while rotating the cylindrical barrels about the rotary shaft 106, as shown by an arrow in Fig.5, thereby forming a deposited film of aluminum on the surface of each of the rare earth metal-based permanent magnets 130 in the cylindrical barrels 105.

[0003]

[PROBLEM TO BE SOLVED BY THE INVENTION]

The deposited-film forming apparatus shown in Fig.5 is capable of treating a large amount of the work pieces and excellent in productivity. However, damage may be observed in some cases on the deposited film of aluminum formed on each of the rare earth metal-based permanent magnets. This damage exerts an adverse influence to the provision of a corrosion resistance

to the rare earth metal-based permanent magnets, causing the increase in yield to be impeded.

Accordingly, it is an object of the present invention to provide a deposited-film forming apparatus capable of forming a deposited film of aluminum or the like on the surface of each of rare earth metal-based permanent magnets at a high quality in respect of a corrosion resistance and the like and at a low cost, wherein the damaging of the deposited film of aluminum can be inhibited.

[0004]

[MEANS FOR SOLUTION OF PROBLEM]

The present inventors have made various reviews with the foregoing in view and as a result, they have found that the damaging of the deposited film of aluminum formed on the surface of each of the rare earth metal-based permanent magnets is directly caused mainly by the collision of the magnets against one another and the rubbing between the magnets and the barrel during the deposited-film forming step. More specifically, in the deposited-film forming apparatus shown in Fig.5, the distance between the cylindrical barrel and the evaporating section is not varied. For this reason, the rare earth metal-based permanent magnets are always stirred in a fixed area near to the evaporating section and heated by a radiant heat from the evaporating section. Thus, the deposited film of aluminum formed on the surface of each of the magnets is softened by a rise in temperature of the magnets due to the above fact, whereby

the deposited film is liable to be damaged.

[0005]

The present invention has been accomplished based on the above knowledge, and to achieve the above object, according to claim 1, there is provided a first deposited-film forming apparatus comprising an evaporating section for a depositing material, and a tubular barrel formed of a mesh net for accommodation of work pieces, on each of the surfaces of which a depositing material is to be deposited, the evaporating section and the tubular barrel being mounted in a vacuum-treating chamber, wherein the tubular barrel is supported outside a horizontal rotary shaft of a support member rotatable about the rotary shaft, for rotation about the rotary shaft, so that the distance between the tubular barrel rotated about the rotary shaft of the support member and the evaporating section can be varied by rotating the support member.

According to claim 2, in addition to claim 1, a plurality of the tubular barrels are supported in an annular shape outside the rotary shaft of the support member.

According to claim 3, there is provided a second deposited-film forming apparatus comprising an evaporating section for a depositing material, and a tubular barrel rotatable about a horizontal rotary shaft and formed of a mesh net for accommodation of work pieces, on each of the surfaces of which a depositing material is to be deposited, the evaporating section and the tubular barrel being mounted in a vacuum-treating chamber.

wherein the inside of the tubular barrel is divided into two or more accommodating sections, the accommodating sections being defined, so that the distance between the accommodating section and the evaporating section can be varied by rotating the tubular barrel.

According to claim 4, in addition to claim 3, the inside of the tubular barrel is divided radiately from a rotational axis into two or more accommodating sections.

According to claim 5, there is provided a process for forming a deposited film using a deposited-film forming apparatus according to any of claims 1 to 4.

According to claim 6, in addition to claim 5, the work piece is a rare earth metal-based permanent magnet.

According to claim 7, in addition to claim 5 or 6, the depositing material is at least one material selected from the group consisting of aluminum, zinc, tin and magnesium and an alloy containing at least one of these metal components.

[0006]

[MODE FOR CARRYING OUT THE INVENTION]

A typical example of a work piece on which a deposited-film is formed in a deposited-film forming apparatus according to the present invention, is a rare earth metal-based permanent magnet. However, the work piece is not limited to the rare earth metal-based permanent magnet, and may be any piece on which a deposited film can be formed.

[0007]

The deposited-film forming apparatus according to the present invention is utilized for formation of a deposited film using a depositing material such as a metal and an alloy, and among others, a soft metal or an alloy containing a soft metal component(s), e.g., aluminum, zinc, tin, magnesium, or an alloy containing at least one of these metal components. A film formed using any of these depositing material contributes to an enhancement in corrosion resistance of a work piece, either as it is, or when it has another film formed on a surface thereof.

[0008]

The deposited-film forming apparatus according to the present invention can be used as an apparatus for forming a deposited film in a vacuum vapor deposition process. In addition, it can be used as an apparatus for forming a deposited film in an ion plating process.

[0009]

A deposited-film forming apparatus according to a first embodiment of the present invention will be described below. This deposited-film forming apparatus includes an evaporating section for a depositing material, and a tubular barrel formed of a mesh net for accommodation of work pieces, on each of the surfaces of which a depositing material is to be deposited. The evaporating section and the tubular barrel are mounted in a vacuum-treating chamber. The tubular barrel is supported outside a horizontal rotary shaft of a support member rotatable about the rotary shaft, for rotation about the rotary shaft,

so that the distance between the tubular barrel rotated about the rotary shaft of the support member and the evaporating section can be varied by rotating the support member. The outline of one example of the deposited-film forming apparatus (an apparatus for forming a deposited film of aluminum on the surface of each of rare earth metal-based permanent magnets) will be described below with the drawings.

[0010]

Fig.1 is a diagrammatic front view (a partially perspective view) of the inside of a vacuum-treating chamber 1 connected to an evacuating system (not shown).

Two support members 7 rotatable about a rotary shaft 6 are disposed side-by-side in an upper area in the chamber. Six cylindrical barrels 5 formed of a mesh net of a stainless steel are supported in an annular shape outside the rotary shaft 6 of the support member 7 by support shaft 8 for rotation about the rotary shaft 6. A plurality of boats 2, which are evaporating sections for evaporating aluminum as a depositing material, are disposed on a boat support base 4 risen on a support table 3 in a lower area in the chamber.

An aluminum wire 9, which is a depositing material, is retained and wound around a feed reel 10 below the support table 3. A proceeding end of the aluminum wire 9 is guided to above the boat 2 by a thermal resistant protective tube 11 facing toward an inner surface of the boat 2. A notched window 12 is provided in a portion of the protective tube 11, and feeding gears 13

are mounted in correspondence to the notched window 12 to come into direct contact with the aluminum wire 9, so that aluminum is constantly supplied into the boat 2 by feeding the aluminum wire 9.

[0011]

Fig.2 is a diagrammatic perspective view showing the six cylindrical barrels 5 formed of the mesh net of a stainless steel and supported in the annular shape outside the rotary shaft 6 of the support member 7 by the support shaft 8 for rotation about the rotary shaft 6, so that they can be rotated about the rotary shaft 6 (the cylindrical barrels are supported in two series and hence, the total number of the cylindrical barrels supported is twelve) (magnets are still not accommodated).

[0012]

When the support member 7 is rotated about the rotary shaft 6 (see an arrow in Fig.1), the cylindrical barrel 5 supported by the support shaft 8 outside the rotary shaft 6 of the support member 7 is rotated about the rotary shaft 6 in response to the rotation of the support member 7. As a result, the distance between the individual barrel and the evaporating section disposed below the support member is varied, whereby an effect is provided, which will be described below.

The cylindrical barrel located at a lower portion of the support member 7 is close to the evaporating section. Therefore, a deposited film of aluminum is formed with a good efficiency on a surface of each of rare earth metal-based permanent magnets

30 accommodated in this cylindrical barrel. On the other hand, rare earth metal-based permanent magnets accommodated in the cylindrical barrel moved away from the evaporating section are released from the heating and cooled by an amount corresponding to a distance from the evaporating section. Therefore, during this time, the softening of a deposited film of aluminum formed on a surface of each of the magnets is inhibited. In this way, if this deposited-film forming apparatus is used, the efficient formation of the deposited film of aluminum and the inhibition of the softening of the formed film of aluminum can be achieved simultaneously.

[0013]

The deposited-film forming apparatus according to the first embodiment of the present invention is advantageous in respect of that it exhibits the above-described effect and has advantages which will be described below.

Even when a mass treatment is carried out, it is advantageous that magnets are placed in a smaller amount into each of the cylindrical barrels in this deposited-film forming apparatus, rather than in a larger amount into a single cylindrical barrel in the prior art deposited-film forming apparatus. In this case, the frequency of collision of the magnets against one another within the barrel can be reduced, and hence, it is possible to inhibit the cracking and breaking of the magnets. In the prior art, for the purpose of the reduction of the frequency of collision of the magnets against one another

within the barrel, dummies (e.g., ceramic balls having a diameter of 10 mm) accommodated along with magnets in the barrel may be used in some cases. However, the use of this deposited-film forming apparatus eliminates the need for use of the dummies, and can enhance the efficiency of the formation of deposited films on the magnets. In addition, it is possible to eliminate labor for placing the magnets into a holder for protecting the magnets (for example, a spring-like cylindrical member which is formed by winding a linear material with a gap left and which has spiral faces at opposite ends, so that magnets can be accommodated in the cylindrical member). Further, the cylindrical barrel can be formed at a size ensuring that the cylindrical barrel is easy to handle and detachable from the deposited-film forming apparatus, and thus, one barrel can be consistently used at the deposited-film forming step and at preceding and succeeding steps (for example, the preceding step may be a blast treatment, and the succeeding step may be a peening treatment and a subsequent chemical conversion film forming treatment). Therefore, the need for carrying out an operation for transferring the magnets between the steps is eliminated and hence, it is possible to inhibit the occurrence of the cracking and breaking of the magnets, which may be caused during transferring of the magnets and in addition, to eliminate labor for the transferring operation.

[0014]

In the deposited-film forming apparatus shown in Figs.1

and 2, the support member 7 for supporting the cylindrical barrel 5 is disposed in the upper area in the vacuum-treating chamber 1. The boat 2, which is the evaporating section, is disposed in the lower area in the chamber 1, but the positional relationship between the support member and the evaporating section is not limited to the above relationship. The support member and the evaporating section may be disposed at any locations, if they are in a positional relationship ensuring that the distance between the cylindrical barrel and the evaporating section can be varied by rotating the support member. However, if the boat is disposed outside the support member, the distance between the support member and the boat can be set in a wide range within the internal space in the vacuum-treating chamber. Therefore, it is possible to easily set a distance desirable for efficiently forming a deposited film and inhibiting the softening of the formed deposited film. In addition, even when the depositing material is evaporated while being molten to conduct the formation of a deposited film, each of the members or components can be easily disposed and is excellent in handleability.

In addition, in the deposited-film forming apparatus shown in Figs.1 and 2, the six cylindrical barrels 5 are supported on one surface of one of the support members 7 (the cylindrical barrels are supported in two series and hence, the total number of the cylindrical barrels supported is twelve), but the number of the cylindrical barrels supported on one of the support members is not limited to six and may be one.

The cylindrical barrel 5 may be supported, so that by rotating the support member 7, it can be rotated about the rotary shaft 6 of the support member 7 and can be also rotated about its axis.

The shape of the barrel is not limited to the cylindrical shape, and the barrel may be polygonal in section such as hexagonal and octagonal, if it is tubular.

Examples of the mesh net include those made of a stainless steel and the like. The mesh net may be made using a net-shaped plate produced by punching or etching a stainless plate, or may be made by knitting a linear stainless steel.

[0015]

A deposited-film forming apparatus according to a second embodiment of the present invention will be described below. This deposited-film forming apparatus includes an evaporating section for a depositing material, and a tubular barrel rotatable about a horizontal rotary shaft and formed of a mesh net for accommodation of work pieces, on each of the surfaces of which a depositing material is to be deposited. The evaporating section and the tubular barrel are mounted in a vacuum-treating chamber. The inside of the tubular barrel is divided into two or more accommodating sections. The accommodating sections are defined, so that the distance between the accommodating section and the evaporating section can be varied by rotating the tubular barrel. The outline of one example of the deposited-film forming apparatus (an apparatus for forming a deposited film of aluminum

on the surface of each of rare earth metal-based permanent magnets) will be described below with the drawings.

[0016]

Fig.3 is a diagrammatic front view of the inside of a vacuum-treating chamber 51 connected to an evacuating system (not shown).

Two cylindrical barrels 55 formed of a mesh net of a stainless steel are disposed side-by-side in an upper area in the chamber for rotation about a horizontal rotary shaft 56. The inside of the cylindrical barrel 55 is divided radiately from a rotational axis into six accommodating sections fan-shaped in section. A plurality of boats 52, which are evaporating sections for evaporating aluminum as a depositing material, are disposed on a boat support base 54 risen on a support table 53 in a lower area in the chamber.

An aluminum wire 59, which is a depositing material, is retained and wound around a feed reel 60 below the support table 53. A proceeding end of the aluminum wire 59 is guided to above the boat 52 by a thermal resistant protective tube 61 facing toward an inner surface of the boat 52. A notched window 62 is provided in a portion of the protective tube 61, and feeding gears 63 are mounted in correspondence to the notched window 62 to come into direct contact with the aluminum wire 59, so that aluminum is constantly supplied into the boat 52 by feeding the aluminum wire 59.

[0017]

Fig. 4 is a diagrammatic perspective view of the cylindrical barrel 55 rotatable about the horizontal rotary shaft 56 and formed of a mesh net, the inside of which is divided radiately from the rotational axis into the six accommodating sections fan-shaped in section (magnets are still not accommodated).

[0018]

When the cylindrical barrel 55 is rotated about the rotary shaft 56 (see an arrow in Fig.3), the distance between the individual accommodating section defined in the cylindrical barrel and the evaporating section disposed below the accommodating sections is varied, whereby an effect is provided, which will be described below.

The accommodating section located at a lower portion of the cylindrical barrel 55 is close to the evaporating section. Therefore, a deposited film of aluminum is formed with a good efficiency on a surface of each of rare earth metal-based permanent magnets 80 accommodated in this accommodating section. On the other hand, rare earth metal-based permanent magnets accommodated in the accommodating section moved away from the evaporating section are released from the heating and cooled by an amount corresponding to a distance from the evaporating section. Therefore, during this time, the softening of a deposited film of aluminum formed on a surface of each of the magnets is inhibited. In this way, if this deposited-film forming apparatus is used, the efficient formation of the deposited film of aluminum and the inhibition of the softening

of the formed film of aluminum can be achieved simultaneously.

[0019]

The deposited-film forming apparatus according to the second embodiment of the present invention is advantageous in respect of that it exhibits the above-described effect and has advantages which will be described below.

Even when a mass treatment is carried out, it is advantageous that magnets are placed in a smaller amount into each of the accommodating sections in this deposited-film forming apparatus, rather than in a larger amount into a cylindrical barrel in the prior art deposited-film forming apparatus. In this case, the frequency of collision of the magnets against one another within the barrel can be reduced, and hence, it is possible to inhibit the cracking and breaking of the magnets. In the prior art, for the purpose of the reduction of the frequency of collision of the magnets against one another within the barrel, dummies (e.g., ceramic balls having a diameter of 10 mm) accommodated along with magnets in the barrel may be used in some cases. However, the use of this deposited-film forming apparatus eliminates the need for use of the dummies, and can enhance the efficiency of the formation of deposited films on the magnets. In addition, it is possible to eliminate labor for placing the magnets into a holder for protecting the magnets (for example, a spring-like cylindrical member which is formed by winding a linear material with a gap left and which has spiral faces at opposite ends, so that magnets can be accommodated in

the cylindrical member).

[0020]

In the deposited-film forming apparatus shown in Figs.3 and 4, the cylindrical barrel 55 is disposed in the upper area in the vacuum-treating chamber 51, and the inside of the cylindrical barrel 55 is divided radiately from the rotational axis into the six accommodating sections fan-shaped in section. The boat 52, which is the evaporating section, is disposed in the lower area in the chamber 51. The positional relationship between the cylindrical barrel and the evaporating section is not limited to the above relationship. The cylindrical barrel and the evaporating section may be disposed at any locations, if they are in a positional relationship ensuring that the distance between the accommodating section and the evaporating section can be varied by rotating the cylindrical barrel.

In the deposited-film forming apparatus shown in Figs.3 and 4, the inside of the cylindrical barrel is divided radiately from the rotational axis into the six accommodating sections fan-shaped in section, but the accommodating sections may be defined in the cylindrical barrel in any dividing manner, if the distance between the accommodating section and the evaporating section can be varied by rotating the cylindrical barrel.

The shape of the barrel is not limited to the cylindrical shape, and the barrel may be polygonal in section such as hexagonal and octagonal, if it is tubular.

Examples of the mesh net include those made of a stainless steel and the like. The mesh net may be made using a net-shaped plate produced by punching or etching a stainless plate, or may be made by knitting a linear stainless steel.

[0021]

[EXAMPLES]

The deposited-film forming apparatus according to the present invention will be further described in detail by comparison of the following examples with comparative examples. The deposited-film forming apparatus according to the present invention is not limited to such examples. The following examples and comparative examples were carried out using sintered magnets having dimensions of 30mm x 15mm x 6mm and having a composition of 14Nd-79Fe-6B-1Co and produced by pulverizing a known cast ingot and then subjecting the resulting powder to a pressing, a sintering, a heat treatment and a surface working, for example, as described in US Patent Nos.4,770,723 and 4,792,368 (such sintered magnets will be referred to as magnet test pieces hereinafter).

[0022]

Example 1:

The following experiment was carried out using the deposited-film forming apparatus shown in Figs.1 and 2. The cylindrical barrel used in this experiment was made of a stainless steel at a diameter of 110 mm and a length of 530 mm. The six cylindrical barrels were supported on one support member (the

total number of the cylindrical barrels supported in two series was twelve).

Each of the magnet test pieces was subjected to a shot blasting, whereby an oxide layer formed on a surface of each of the magnet test pieces by a surface treatment at a preceding step was removed. Sixty-nine magnet test pieces (five of which were magnets on each of which Thermo Label (which is a trade name and made by Nichiyu Giken Kogyo Co., Ltd) was adhered) were placed into each of the twelve cylindrical barrels. Therefore, a total of 828 magnet test pieces were accommodated in the twelve cylindrical barrels. The vacuum-treating chamber was evacuated under $1 \times 10^{-3}$ Pa, and the magnet test pieces were then subjected to a spattering for 20 minutes under conditions of an argon (Ar) gas pressure of 1 Pa and a bias voltage of -500 V, while rotating the support members at 1.5 rpm, whereby the surfaces of the magnet test pieces were cleaned. Subsequently, an aluminum wire used as a depositing material was heated and evaporated for ionization under conditions of an Ar gas pressure of 1 Pa and a bias voltage of -100 V, whereby a deposited film of aluminum was formed on a surface of each of the magnet test pieces for 12 minutes by an ion plating process. An average highest temperature of the magnet test pieces having the Thermo Label adhered thereto was measured and as a result, it was 170°C.

The magnet test pieces were left to cool and then, examined for the damaging of the deposited film of aluminum formed on

each of their surfaces and for the cracking and breaking of the magnet test pieces themselves. A thickness of the deposited film of aluminum on each of the magnet test pieces (except the magnet test pieces having portions exposed due to the damaging or the cracking and breaking) was measured using a fluorescence X-ray thickness-meter (SFT-7000 made by Seiko Instruments and Electronics, Ltd.). Results (average value of n = 10) of the measurement are shown in Table 1.

The magnet test pieces each having the deposited film of aluminum on its surface were left accommodated in the cylindrical barrels without being transferred into other barrels. Then, the magnet test pieces were subjected to a shot peening treatment in which spherical glass beads having an average grain size of 120 μm and a Mohs hardness of 6 were injected to under an injection pressure of 1.5 $kg/cm^2$ for 5 minutes along with a pressurized gas comprising $N_2$ gas. The number of those of the magnet test pieces having the deposited films of aluminum and subjected to the shot peening treatment, whose portions exposed due to the damaging of the deposited films of aluminum or the cracking and breaking of the magnet test pieces themselves (i.e., the defective products) was examined. A result is shown in Table 1.

The magnet test pieces having the deposited film of aluminum (except the magnet test pieces having portions exposed due to the damaging or the cracking and breaking) were subjected

to a corrosion-resistance acceleration test which comprises leaving the magnet test pieces to stand under high-temperature and high-humidity conditions of a temperature of 80°C and a relative humidity of 90 %, and results (n = 5) are shown in Table 1.

As apparent from Table 1, it is made clear that by carrying out the formation of the deposited film of aluminum on the surface of each of the magnet test pieces using the deposited-film forming apparatus according to the first embodiment of the present invention, the damaging of the deposited film of aluminum and the cracking and breaking of the magnet test pieces themselves can be inhibited, and an excellent corrosion resistance can be provided to each of the magnet test pieces.

[0023]

Example 2:

The following experiment was carried out using the deposited-film forming apparatus shown in Figs.3 and 4. The cylindrical barrel used in this experiment was made of a stainless steel at a diameter of 355 mm and a length of 1,200 mm. The inside of the cylindrical barrel was divided radiately from the rotational axis into six accommodating sections fan-shaped in section.

Each of the magnet test pieces was subjected to a shot blasting, whereby an oxide layer formed on a surface of each of the magnet test pieces by a surface treatment at a preceding

step was removed. 138 Magnet test pieces (five of which were magnets on each of which Thermo Label was adhered) were placed into each of the accommodating sections of the cylindrical barrel. Therefore, a total of 828 magnet test pieces were accommodated in the entire cylindrical barrel. Thereafter, a deposited film of aluminum was formed on a surface of each of the magnet test pieces in the same manner as in Example 1. An average highest temperature of the magnet test pieces having the Thermo Label adhered thereto was measured and as a result, it was 170°C.

The magnet test pieces were left to cool and then, examined for the damaging of the deposited film of aluminum formed on each of their surfaces and for the cracking and breaking of the magnet test pieces themselves. A thickness of the deposited film of aluminum on each of the magnet test pieces (except the magnet test pieces having portions exposed due to the damaging or the cracking and breaking) was measured in the same manner as in Example 1. Results (average value of n = 10) of the measurement are shown in Table 1.

The magnet test pieces each having the deposited film of aluminum on the surface thereof were transferred in a tray made of aluminum and were subjected to a shot peening treatment in the same manner as in Example 1. The magnet test pieces each having the deposited film of aluminum and subjected to the shot peening treatment were examined for the number of defective products. A result is shown in Table 1.

In addition, the magnet test pieces having the deposited film of aluminum (except the magnet test pieces having portions exposed due to the damaging or the cracking and breaking) were subjected to a corrosion-resistance acceleration test similar to that in Example 1, and results (n = 5) are shown in Table 1.

As apparent from Table 1, it is made clear that by carrying out the formation of the deposited film of aluminum on the surface of each of the magnet test pieces using the deposited-film forming apparatus according to the second embodiment of the present invention, the damaging of the deposited film of aluminum and the cracking and breaking of the magnet test pieces themselves can be inhibited, and an excellent corrosion resistance can be provided to each of the magnet test pieces.

[0024]

Comparative Example 1:

The following experiment was carried out using a prior art deposited-film forming apparatus including cylindrical barrel made of a stainless steel at a diameter of 355 mm and a length of 1,200 mm (see Fig.5, the evaporating section being of the same construction as in the deposited-film forming apparatus shown in Fig.1).

Each of the magnet test pieces was subjected to a shot blasting, whereby an oxide layer formed on a surface of each of the magnet test pieces by a surface treatment at a preceding step was removed. 828 Magnet test pieces (five of which were

magnets on each of which Thermo Label was adhered) were placed into the cylindrical barrel. Thereafter, a deposited film of aluminum was formed on a surface of each of the magnet test pieces in the same manner as in Example 1. An average highest temperature of the magnet test pieces having the Thermo Label adhered thereto was measured and as a result, it was 220°C.

The magnet test pieces were left to cool and then, examined for the damaging of the deposited film of aluminum formed on each of their surfaces and for the cracking and breaking of the magnet test pieces themselves. A thickness of the deposited film of aluminum on each of the magnet test pieces (except the magnet test pieces having portions exposed due to the damaging or the cracking and breaking) was measured in the same manner as in Example 1. Results (average value of $n = 10$) of the measurement are shown in Table 1.

The magnet test pieces each having the deposited film of aluminum on the surface thereof were transferred in a tray made of aluminum and were subjected to a shot peening treatment in the same manner as in Example 1. The magnet test pieces each having the deposited film of aluminum and subjected to the shot peening treatment were examined for the number of defective products. A result is shown in Table 1.

In addition, the magnet test pieces having the deposited film of aluminum (except the magnet test pieces having portions exposed due to the damaging or the cracking and breaking) were

subjected to a corrosion-resistance acceleration test similar to that in Example 1, and results (n = 5) are shown in Table 1.

As apparent from Table 1, when the deposited film of aluminum was formed on the surface of each of the magnet test piece using the prior art deposited-film forming apparatus, the number of the defective products was far larger, and the corrosion resistance of the magnet test pieces was poor, as compared with the deposited film of aluminum formed using the deposited-film forming apparatus according to the present invention.

[0025]

The present inventors have made clear that the hardness of the deposited film of aluminum is reduced with a rise in temperature of the magnet, the above-described results have been construed as being due to a difference in degree of rising of the temperature of the magnet during formation of the film.

[0026]

Table 1

| | Thickness (μm) | Number of defective products | Result of corrosion-resistance test |
|---|---|---|---|
| Example 1 | 6.8 | 1 | All magnets were not rusted even after lapse of 500 hours |
| Example 2 | 6.3 | 3 | All magnets were not rusted even after lapse of 500 hours |
| Comparative Example 1 | 7.1 | 17 | Three magnets were rusted after lapse of 300 hours |

[0027]

[EFFECT OF THE INVENTION]

With the deposited-film forming apparatus according to a first embodiment of the present invention, the distance between the tubular barrel and the evaporating section can be varied, unlike the prior art deposited-film forming apparatus and hence, the efficient formation of the deposited film on the surface of each of the work pieces accommodated in the tubular barrel and the inhibition of the softening of the formed film can be achieved simultaneously. Therefore, it is possible to inhibit the damaging of the deposited film formed on the surface of each of the work pieces, and to form a deposited film at a high quality in respect of a corrosion resistance and the like and at low cost.

With the deposited-film forming apparatus according to a second embodiment of the present invention, the distance between the accommodating section defined in the tubular barrel and the evaporating section can be varied and hence, this deposited-film forming apparatus also exhibits an effect similar to that in the deposited-film forming apparatus according to the first embodiment of the present invention.

[BRIEF DESCRIPTION OF THE DRAWINGS]

[Fig.1] A diagrammatic front view of the inside of a vacuum-treating chamber in one example of a deposited-film forming apparatus according to a first embodiment of the present

invention

[Fig.2] A diagrammatic perspective view of cylindrical barrels supported on support members in one example of a deposited-film forming apparatus according to a first embodiment of the present invention

[Fig.3] A diagrammatic front view of the inside of a vacuum-treating chamber in one example of a deposited-film forming apparatus according to a second embodiment of the present invention

[Fig.4] A diagrammatic perspective view of the cylindrical barrel whose inside is divided in one example of a deposited-film forming apparatus according to a second embodiment of the present invention

[Fig.5] A diagrammatic front view of the inside of a vacuum-treating chamber in the prior art deposited-film forming apparatus

[EXPLANATION OF REFERENCE CHARACTERS]

1, 51, 101 vacuum-treating chamber

2, 52, 102 boat (evaporating section)

5, 55, 105 cylindrical barrel

6, 56, 106 rotary shaft

7 support member

8 support shaft

9, 59 aluminum wire

30, 80, 130 rare earth metal-based permanent magnet